Probing gas distribution in LRG halos through the Sunyaev Zel'dovich effect

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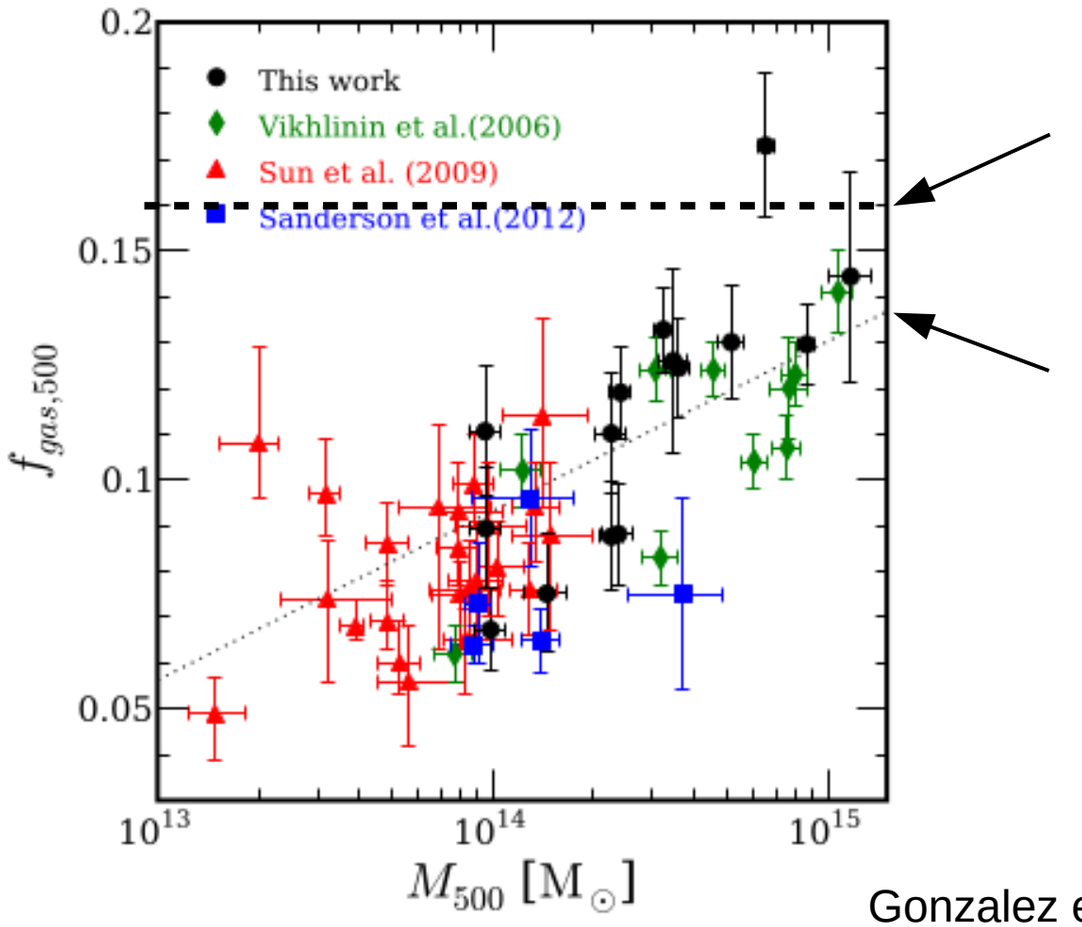
Baryonic effects with (non) self-similarity

The self-similar relation is the relation that does not depend on the scale
, which is valid when the process is dominated by gravity.
The deviation from this relation implies the presence of more complex processes.



Cosmic baryon fraction (Ωb/Ωm)

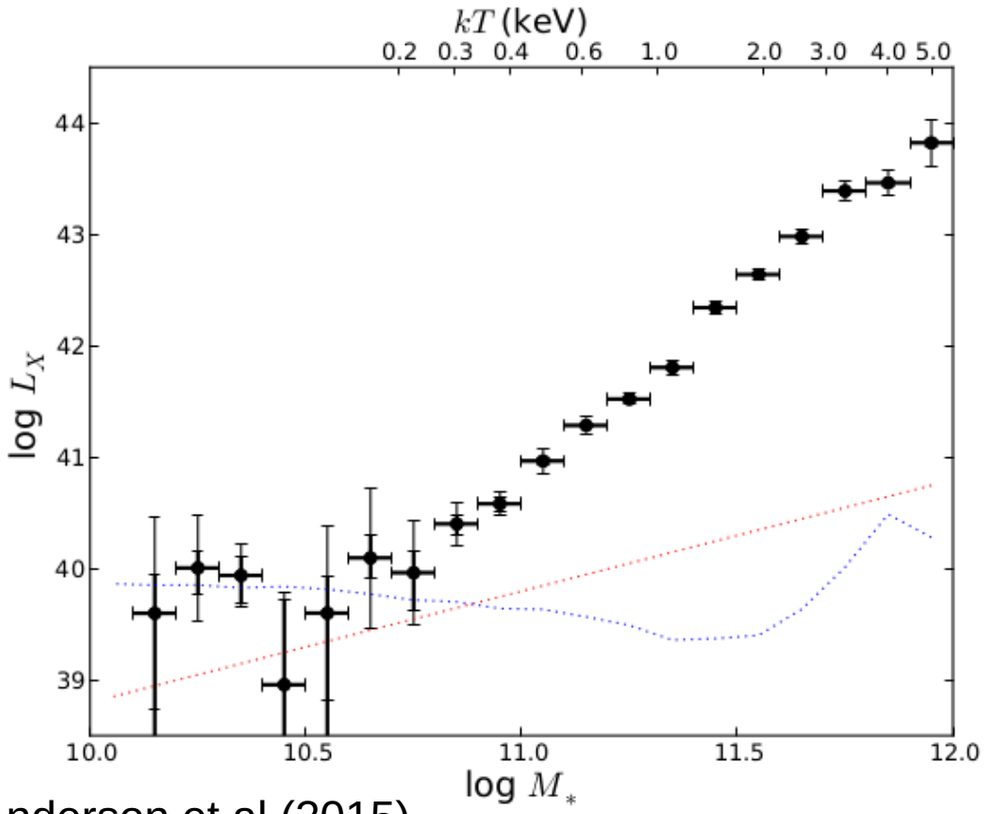
fgas,500 ∝ M500 $^{0.26\pm0.03}$

Gonzalez et al (2013)

X-ray measurement of gas fraction (Mgas/M500) in galaxy clusters shows non self-similarity, which suggests that non-gravitational effect is important.

Gas fraction in galaxy cluster is not self-similar ?

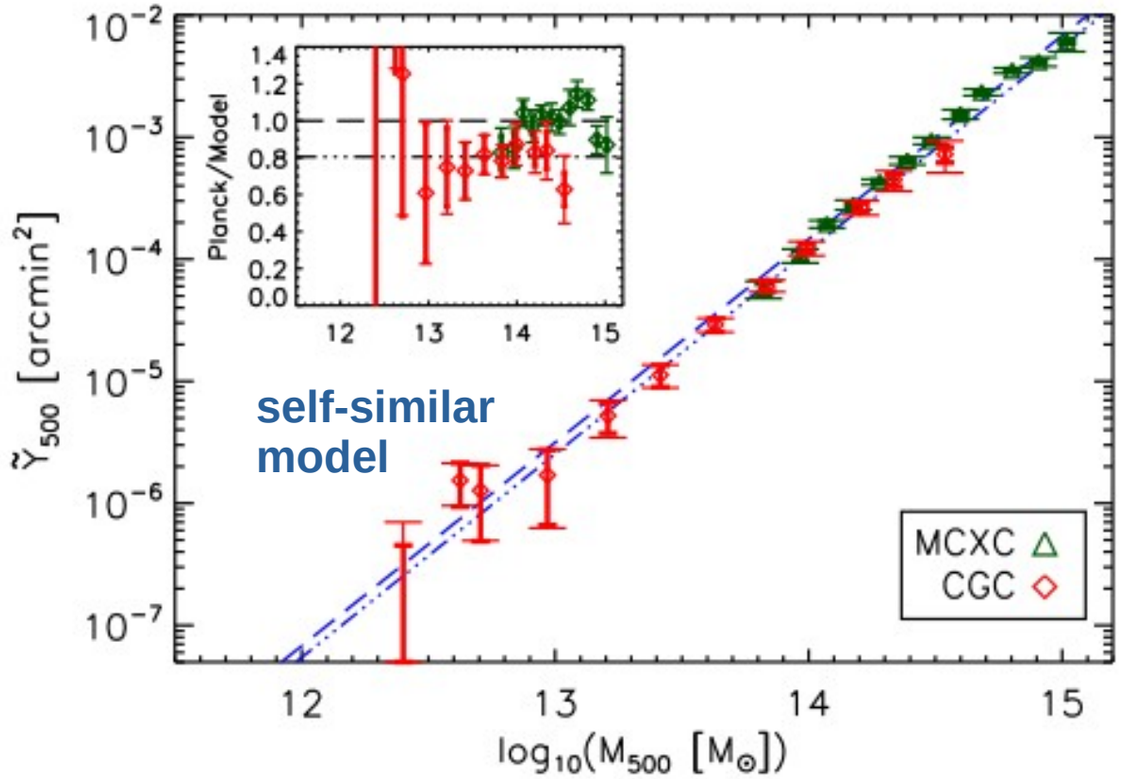
Lx-M scaling relation
from X-ray measurements from ROSAT



Anderson et al (2015)

Not self-similar
The slope is estimated to 1.85±0.15
(1.33 in case of self-similar)

Y-M scaling relation
from SZ measurements from Planck



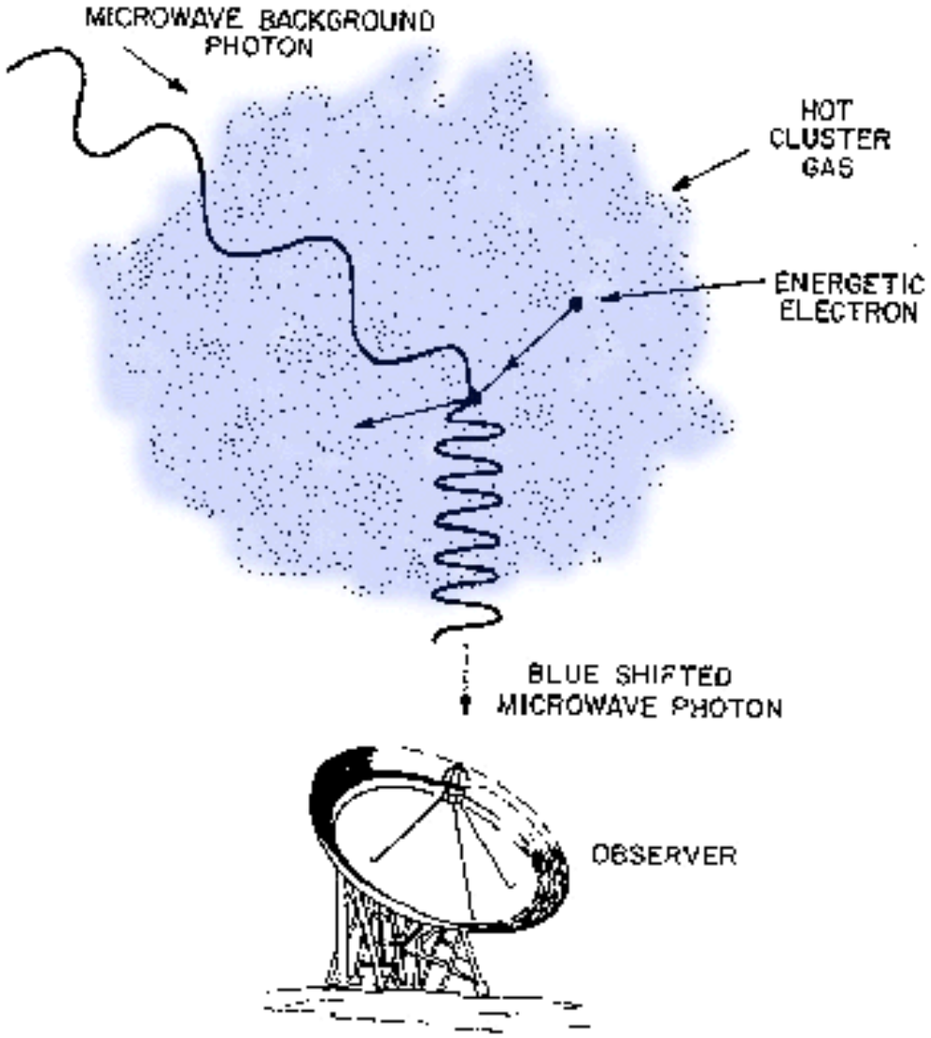
Planck Intermediate Results. XI (2013)

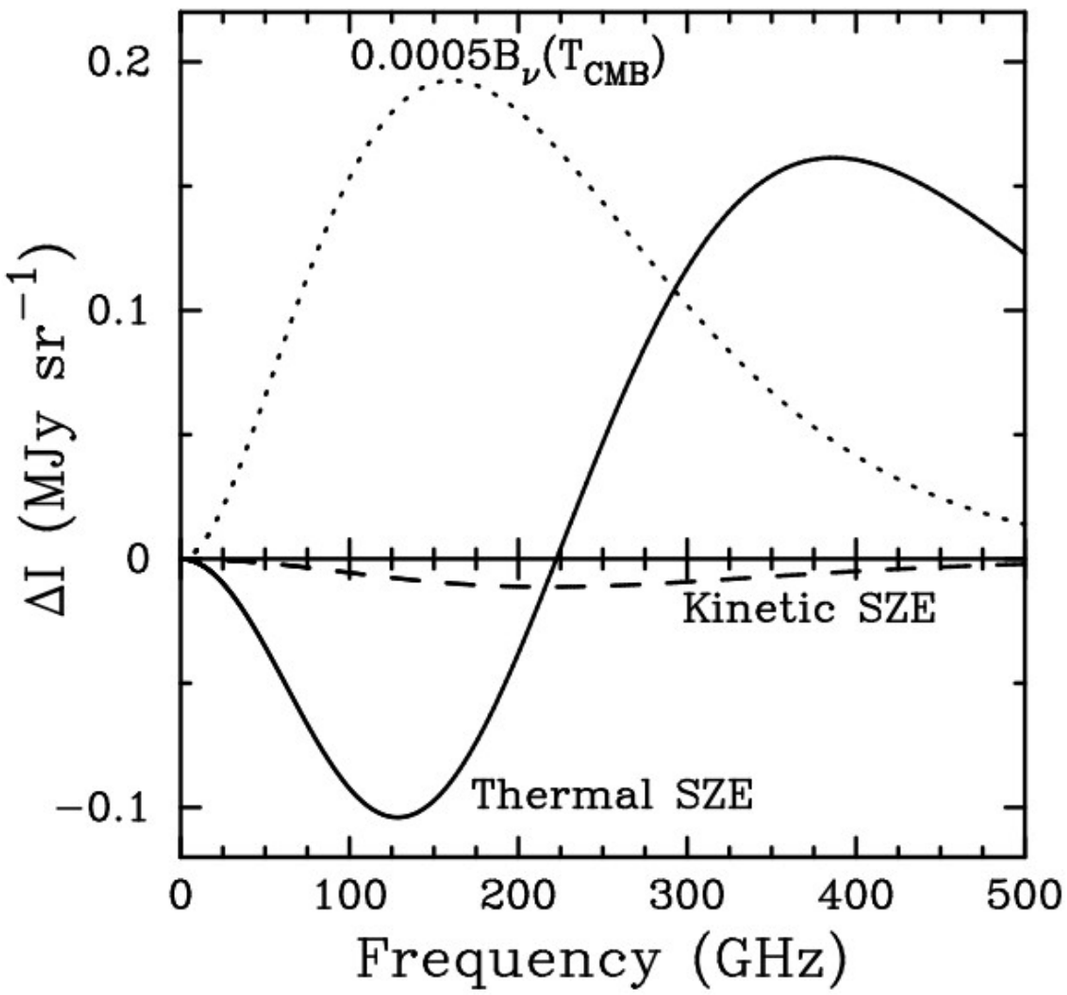
Self-similar

However, there are larger uncertainties in low-mass halos below 10^{14} Msun.

Sunyaev-Zel'dovich(SZ) Effect

SZ effect is the distortion of the CMB spectrum
caused by high energy electrons in galaxy clusters.



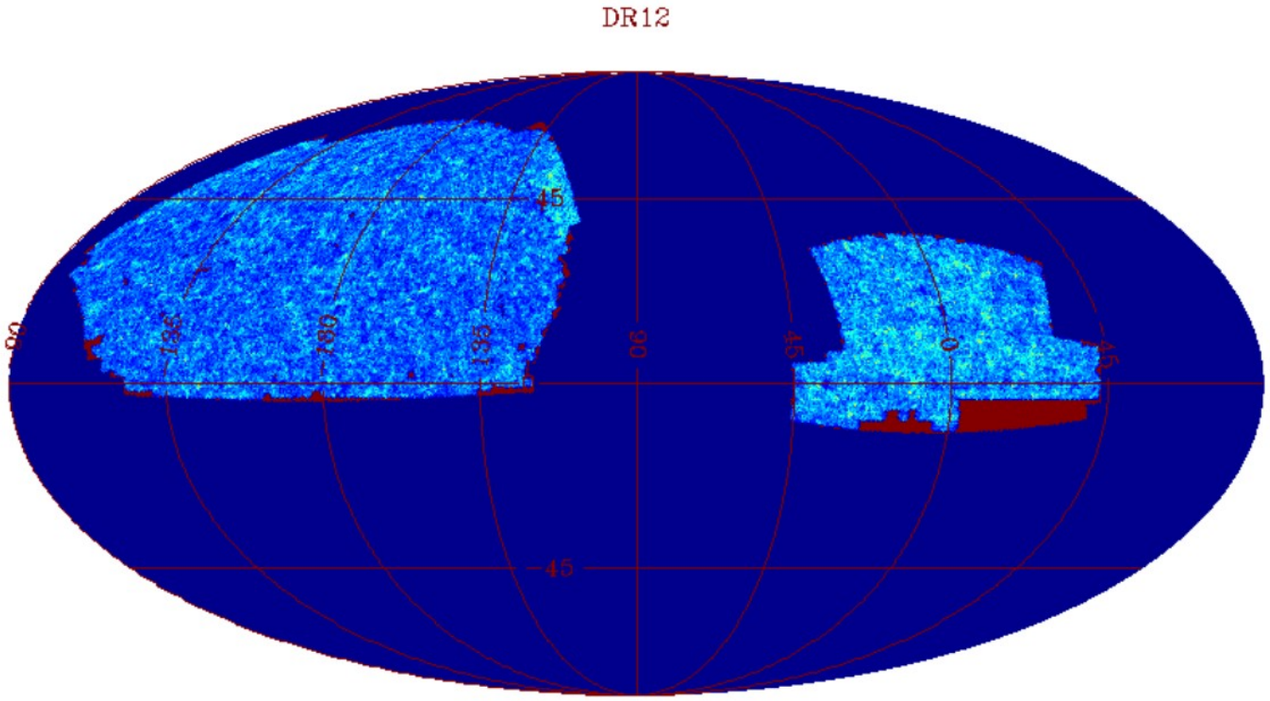


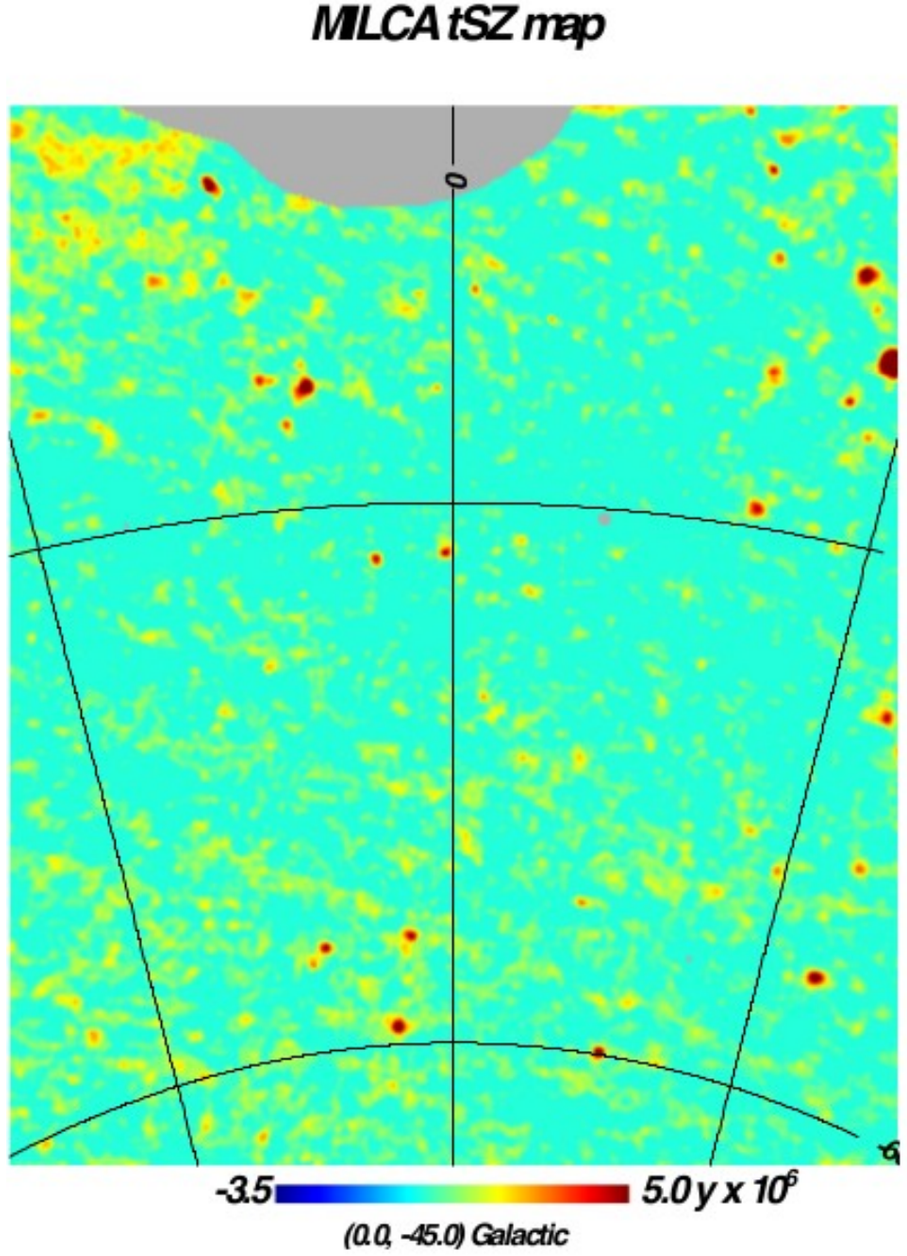
Spectral distortion of the CMB by a galaxy cluster
with T=10 keV, y=1e-4, Vpec=500 km/s (Carlstrom et al 2002)

Data set

~65,000 LRGs from SDSS DR7
(LRG: Luminous red galaxies)

Redshift: $0.16 < z < 0.47$
Stellar mass: $10^{11.2}\,M\odot < M^* < 10^{11.7}\,M\odot$
(in Halo mass: $10^{13}\,M\odot < M_{500} < 10^{14}\,M\odot$)

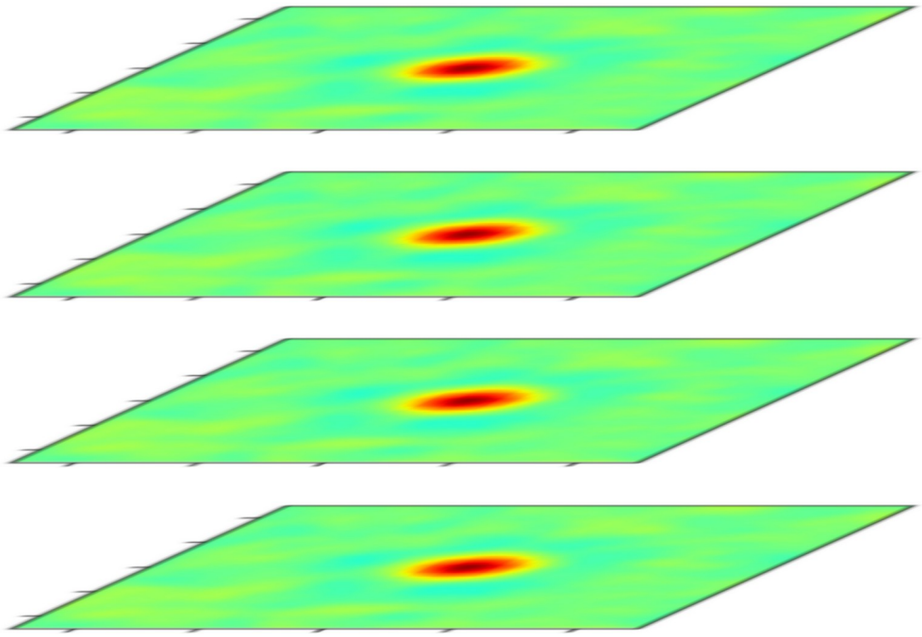




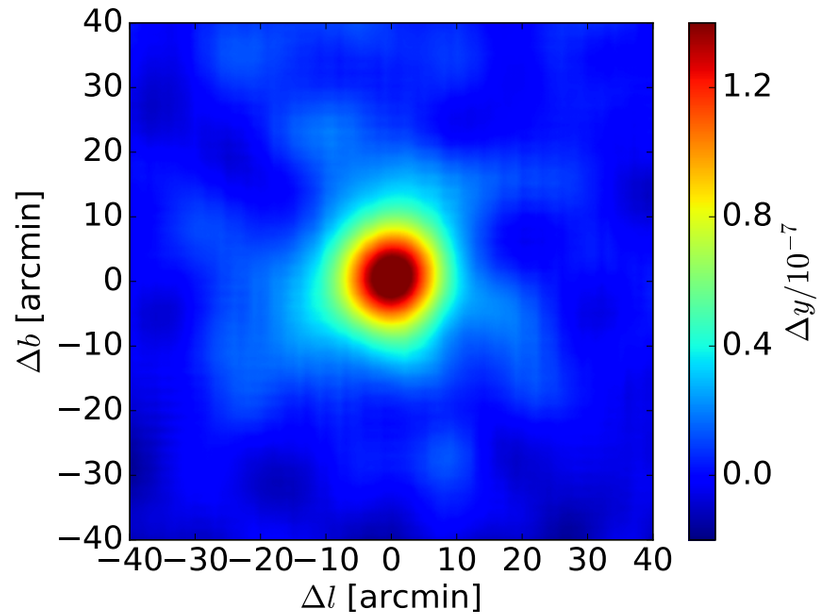
- The LRGs can be used to point the center of galaxy groups and clusters.
- The Planck SZ map probes the hot gas in dark matter halos.

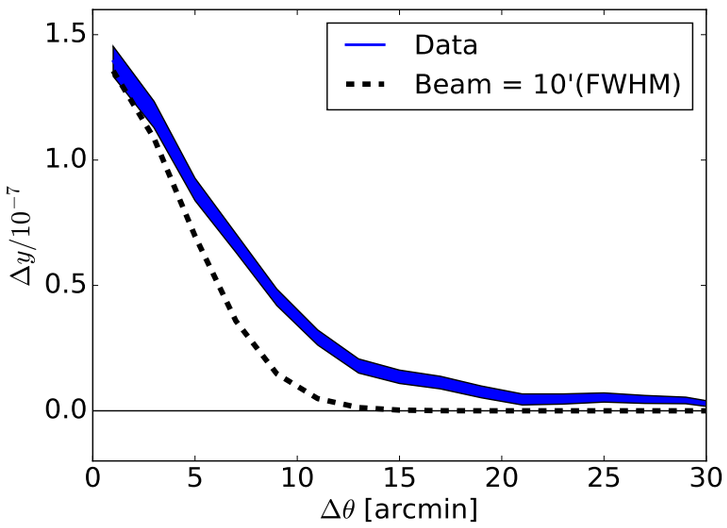
Methodology (Stacking)

We stack the Planck SZ map
at the positions of ~65,000 LRGs.



(Planck SZ map)





The SZ emission is extended out to ∼ 30',
well beyond the extent of the 10' resolution of the Planck SZ map.

cosmo-OWLS hydrodynamical Simulation

• cosmo-OWLS is an extension of the OverWhelmingly Large Simulation project (Schaye et al. 2010). Designed to study cluster cosmology and large scale-structure.

• Suite consists of box-periodic hydrodynamical simulations, with volumes of $(400\ h^{-1}\ \mathrm{Mpc})^3$ and 1024^3 baryon and dark matter particles each.
See Brun et al. (2014); Van Daalen et al. (2014); McCarthy et al. (2014).

• McCarthy et al. (2014) extract ten 5°×5° light-cones with simulated SZ signal out to z=3, with ~10^6 galaxies in each cone.

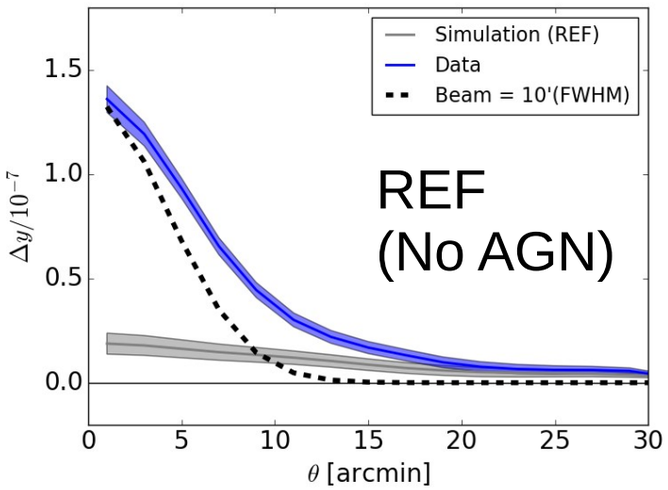
• Each simulation was run with 5 different models of baryon sub-grid physics.
Earlier studies demonstrate that the “AGN 8.0” model reproduces a variety of observed gas features in local groups and clusters of galaxies, selected by optical or X-ray data.

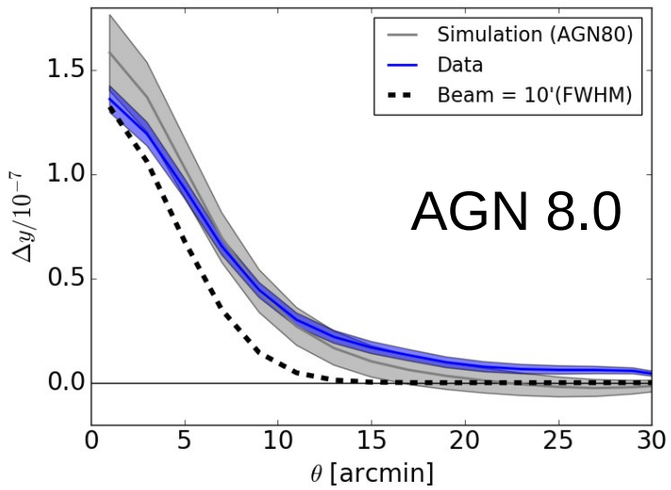
Simulation	UV/X-ray background	Cooling	Star formation	SN feedback	AGN feedback	ΔT_{heat}
NOCOOL	Yes	No	No	No	No	...
REF	Yes	Yes	Yes	Yes	No	...
AGN 8.0	Yes	Yes	Yes	Yes	Yes	$10^{8.0}$ K
AGN 8.5	Yes	Yes	Yes	Yes	Yes	$10^{8.5}$ K
AGN 8.7	Yes	Yes	Yes	Yes	Yes	$10^{8.7}$ K

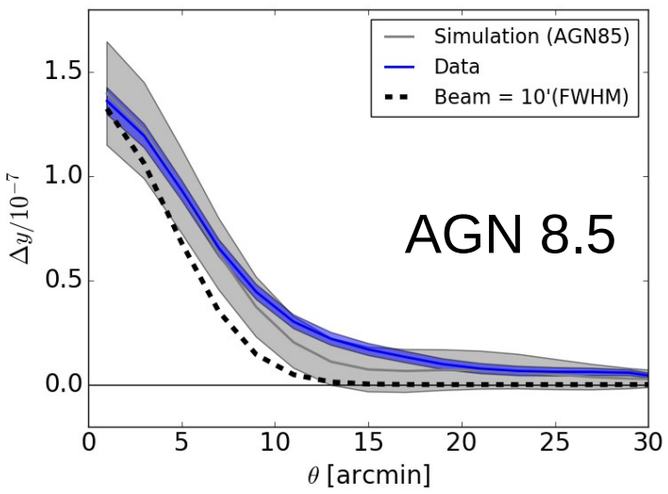
AGN-8.x:

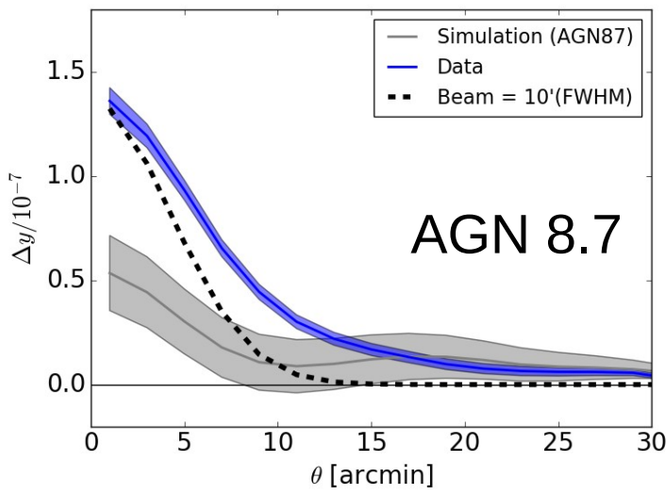
$T_{heat} = 10^{8.x}$ K

Comparison with simulations



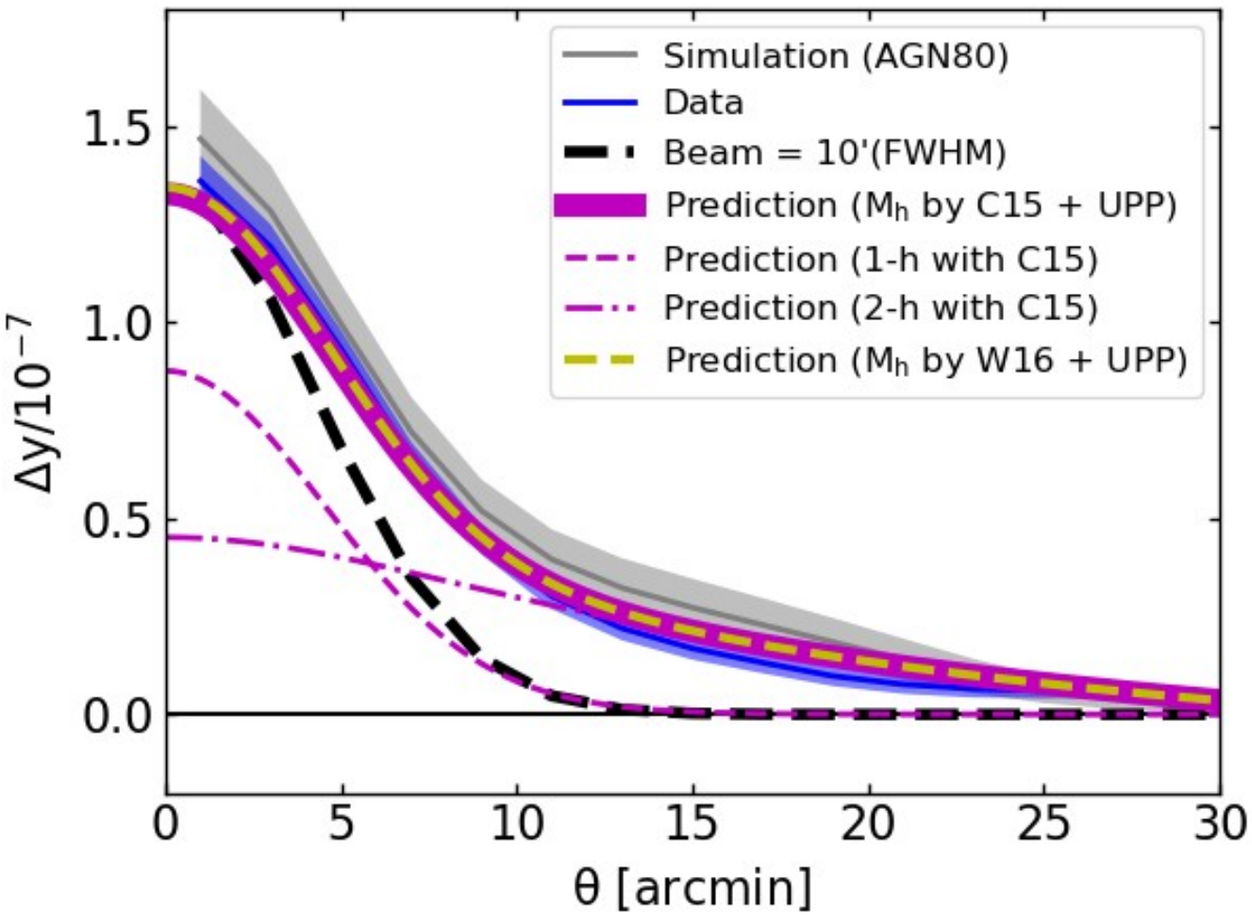






The data agree well with hydro simulations that include AGN feedback, but not without it or bursty AGN model such as AGN 8.7.

Comparison with model prediction



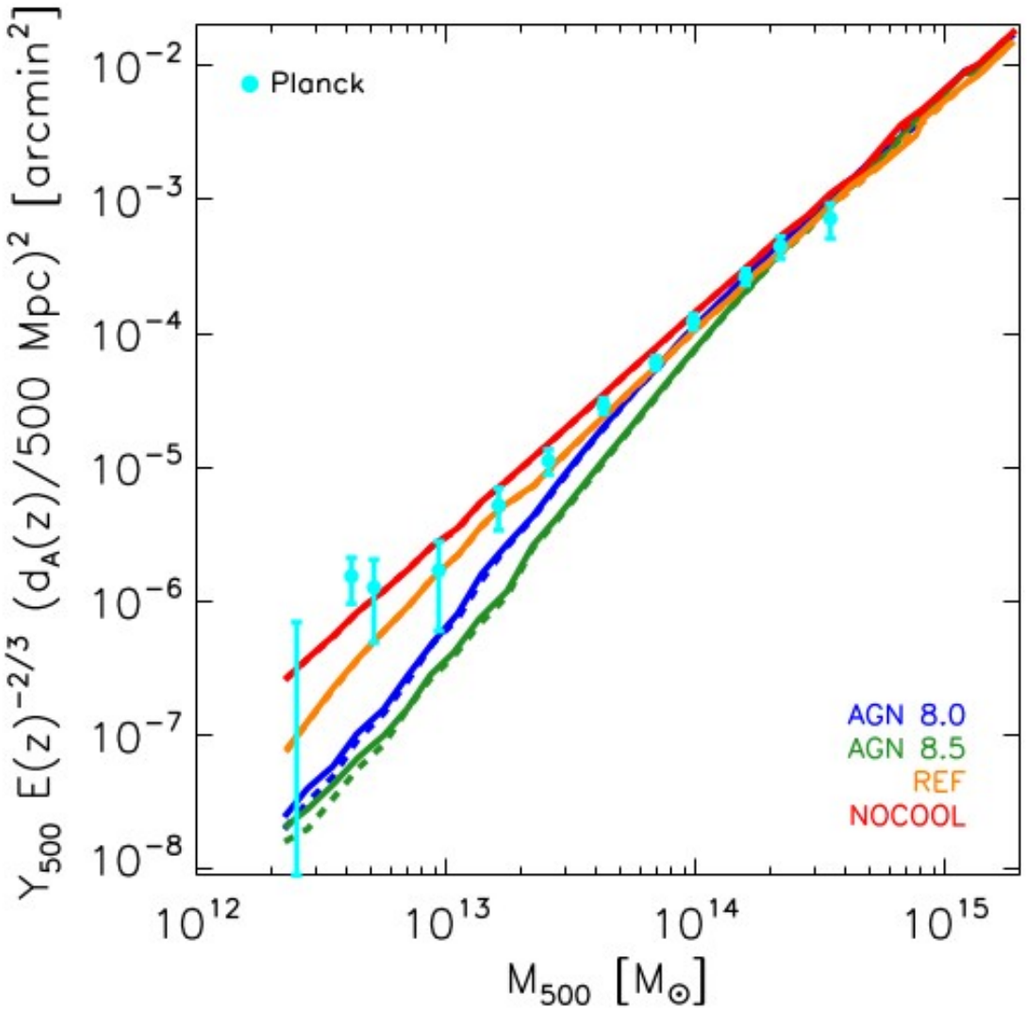
- Halo mass is estimated
using the stellar-to-halo mass relation.
C15: Coupon et al. (2015)
W16: Wang et al. (2016)

- UPP is the Universal Pressure Profile,
measured with galaxy clusters ($10^{14.4}$-$10^{15.3}$ M⊙)
in Planck intermediate results V (2013)

The data agree well with predictions of the halo model using the UPP,
scaled with the self-similar relation.

Interpretation

* Data agree with model prediction using UPP, scaled with self-similar relation.
* Data agree with AGN 8.0 model of the cosmo-OWLS simulations.



Le Brun et al 2015.

The deviation starts to appear below $3*10^{13}$ Msun,
Which is the average mass of the LRG halos.

The angular resolution of the Planck y-map is 10',
while the average angular size of the LRG halos is ~5'.

→ Need better sensitivity to probe lower-mass haloes
as well as higher angular resolution

Summary

- We detect a significant SZ signal around the LRG halos (M500~$10^{13.5}$Msun) out to ~30', well beyond the extent of the 10' beam of the Planck SZ map.

- The measured SZ profile agrees best with the AGN 8.0 model, not without it or bursty AGN model (such as AGN 8.7).

- The measured SZ profile agree with predictions using the halo model and UPP, and we did not find a significant deviation from the UPP, scaled with self-similar relation. But we need a further study with lower-mass halos to confirm it.